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MINISTRY OF THE ENVIRONMENT
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LIME TREATMENT FOR PHOSPHORUS REMOVAL AT THE NEWMARKET/EAST GWILLIMBURY WPCP

AN

INTERIM REPORT

RESEARCH BRANCH
MINISTRY OF THE ENVIRONMENT

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LIME TREATMENT FOR PHOSPHORUS REMOVAL AT THE NEWMARKET/EAST GWILLIMBURY WPCP

By

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Paper No. W2032

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NOTE

This report is not intended to be a complete account of the research work on the lime treatment process at the Newmarket/East Gwillimbury WPCP. It is, rather, a brief account of the process as it has been, and is being, evaluated with a particular emphasis on process and equipment operational problems and process benefits.

1.0 Introduction

The lime treatment process under investigation at the Newmarket/East Gwillimbury WPCP is the result of extensive laboratory model, and pilot and field scale investigations into the use of chemical processes for removing phosphorus at existing sewage treatment plants.

The Newmarket facility is the first full-scale permanent installation of a phosphorus removal process for sewage treatment in Ontario. The lime treatment process was selected for this research and demonstration project because of its proven success in the above mentioned studies and because it was felt that lime would be the most economical chemical, due to its low cost and availability, for widespread use throughout Ontario.

1.1 Existing Facility

The Newmarket/East Gwillimbury WPCP is a 2.0 MIGPD conventional activated sludge plant which was placed into operation in 1963. Design specifications of the plant are as follows:

Primary Treatment

Screening - Screening consists of 1" spacing on manually cleaned bar screens.

Grit Removal - An aerated grit tank of 7 min. detention, with grit removal by an air lift, is provided.

Primary Sedimentation - Two parallel Eimco clarifiers, 30 ft x 30 ft x 11.7 ft side wall depth providing a detention of 1.57 hours, surface loading of 1110 gal/ft^2/day, and weir loading rate of 10,800 gal/ft/day at 2.0 MIGPD.

Secondary Treatment

Aeration - Aeration is provided by twelve 7.5 HP Simcar mechanical surface aerators in three parallel rectangular tanks, each 120 ft x 30 ft x 10.7 ft providing a detention of 0.22 million gallons each, with a design detention time of 8.0 hours.

Secondary Sedimentation - Secondary clarification is provided for by two Eimco clarifiers 35 ft x 35 ft x 13 ft side wall depth, giving 2.4 hours detention, surface loading of 840 gal/ft^2/day, and weir loading rate of 7,870 gal/ft/day at 2.0 MIGPD.

Chlorination - A chlorine contact chamber 61.4 ft x 9 ft x 10.1 ft with a theoretical detention of 25 min. is provided.

Sludge Treatment

Two Stage Digestion System - The primary digester consists of one 40 ft diam. x 21.25 ft side wall depth concrete tank of 0.167 mil gal. capacity. Gas mixing is provided for by a C.P. Lammert gas compressor. The primary digester has a design loading rate of 2.9 lb/cu ft/mo. Secondary digestion takes place in one 40 ft diam. x 23 ft. side wall depth concrete tank with a design loading rate of 1.4 lb/cu ft/mo.

Sludge Disposal

Sludge is disposed of by wet haulage to neighbouring farmers' fields.

1.2 Actual Loading Data

The actual flow to the plant is somewhat below the 2.0 MIGPD design, therefore the actual loadings on the plant processes are lower than design:

Primary Sedimentation:

Sewage flow	1.58 MIGPD
Detention time	2 hours
Hydraulic surface loading	875 gal/day/ft^2

Aeration:

Detention time	10 hours
Volumetric BOD loading	25.4 lb BOD/day/1000 ft^3
Organic load ratio (F:M)	0.79 lb BOD/day/lb MLSS

Secondary Sedimentation:

Detention time	3 hours
Hydraulic surface loading	664 gal/ft^2/day

1.3 Phosphorus Removal facility

The phosphorus removal process, consisting of lime storage, feeding and mixing facilities, was installed during the winter of 1970-71 with operation of the process beginning in early March of 1971.

Figure 1 presents a line diagram of the entire sewage treatment plant including the phosphorus removal process; Figure 2 shows photographs of the actual phosphorus removal process facilities. The lime storage facility consists of a partially

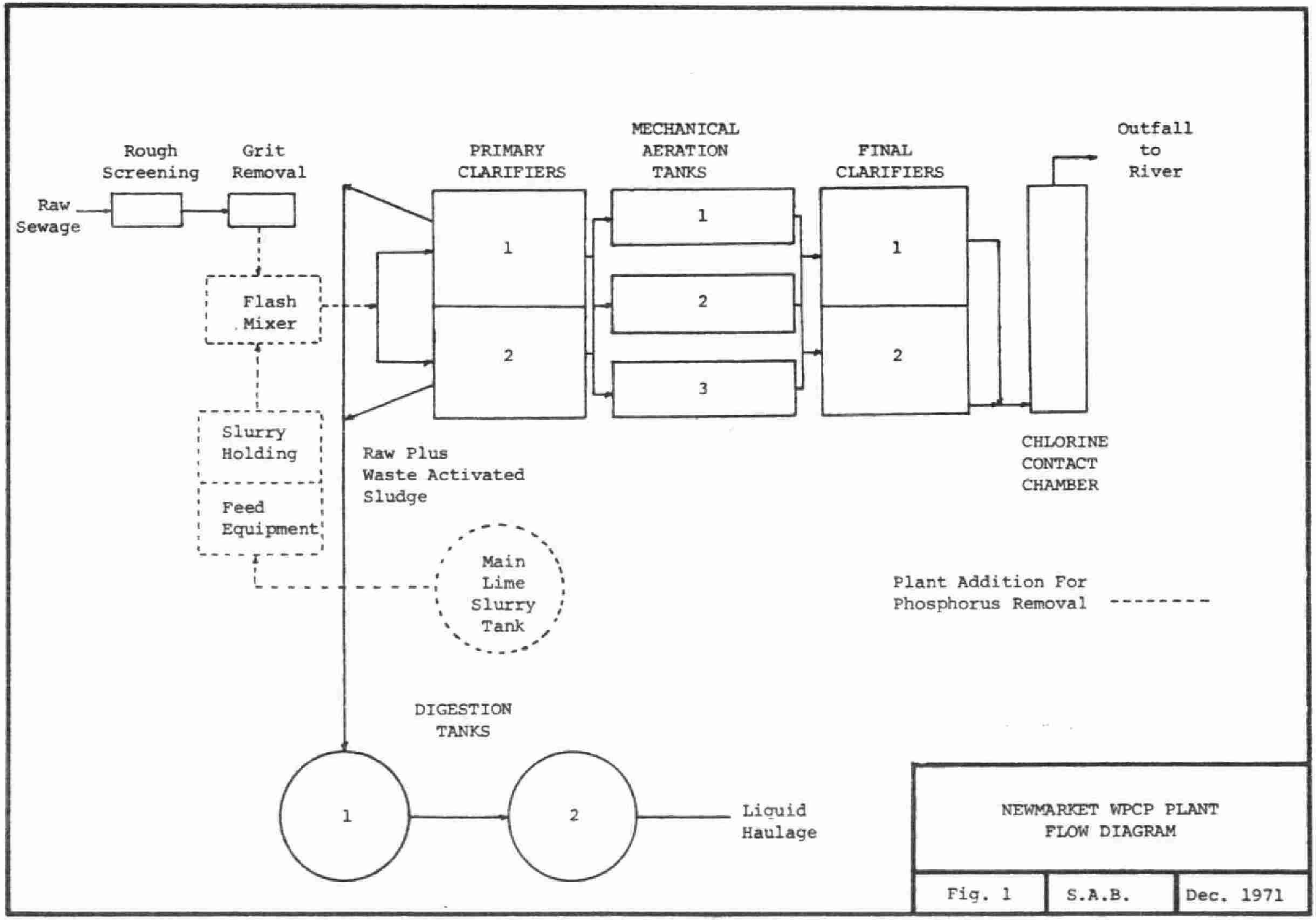
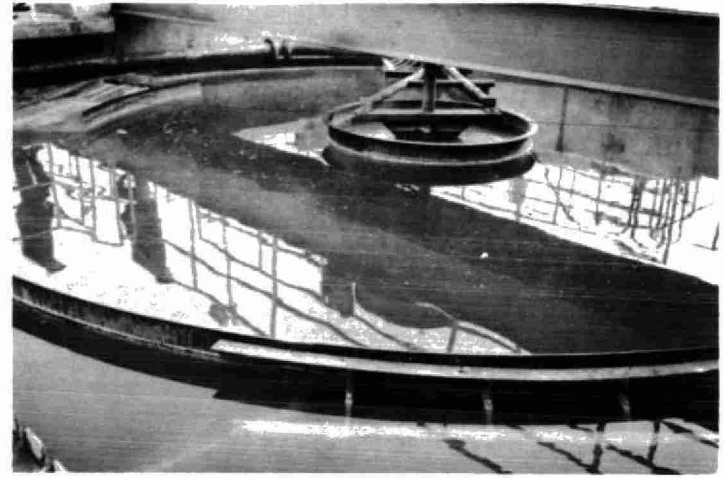
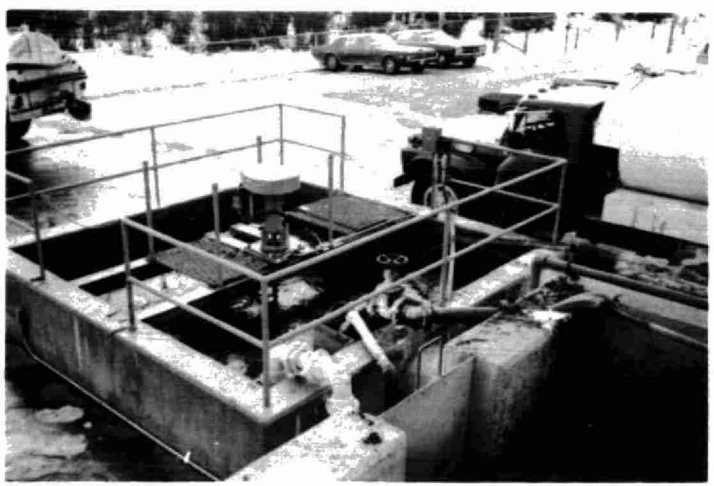

Raw Sewage
Rough Screening
Grit Removal
Flash Mixer
Slurry Holding
Feed Equipment
Main Lime Slurry Tank
PRIMARY CLARIFIERS
1
2
MECHANICAL AERATION TANKS
1
2
3
FINAL CLARIFIERS
1
2
Outfall to River
CHLORINE CONTACT CHAMBER
Raw Plus Waste Activated Sludge
DIGESTION TANKS
1
2
Liquid Haulage
Plant Addition For Phosphorus Removal
NEWMARKET WPCP PLANT
FLOW DIAGRAM
Fig. 1
S.A.B.
Dec. 1971

Figure 2

a) Slurry Tank, Equipment Cell, Day Tank



c) Primary Clarifier



b) Rapid Mix Tank

d) Sludge hauling

buried circular concrete tank 25 feet in diameter and approximately 17 feet in depth with the capacity of storing up to 30 tons of hydrated lime at a 30% by weight slurry. Slurry storage and feeding was used for this installation to provide flexibility for carrying out investigations of the use of a waste carbide lime slurry produced in the manufacture of acetylene.

The lime slurry is kept in suspension by one of two 6-inch centrifugal pumps located, along with the slurry feeding pumps, in the equipment cell shown in Figure 2.

The lime slurry feeding pumps are paced to the raw sewage flow as measured through a parshall flume at the head of the plant. The rate of lime feed is thereby automatically controlled to maintain a constant, pre-determined, dosage of lime in the sewage.

The lime slurry is fed to the rapid mix tank shown in Figure 2 where the lime enters into rapid and intimate mixing with the raw sewage. A contact time of about 8 minutes is provided.

The lime-sewage mixture then flows to the primary clarifiers and on through the plant process.

1.4 Performance Prior to Lime Addition

While the phosphorus removal facility was being constructed, an intensive study was carried out on the existing plant process to provide for future comparative purposes. Under the actual loading conditions outlined above, Table 1 presents the average raw sewage, primary effluent and final effluent data based on 24-hour composite samples for a six-week period prior to the start-up of the lime treatment facility.

Examination of the data in Table 1 indicates a high degree of BOD and SS removal, 92% and 95% respectively. The phosphorus removal, 39%, is within that range expected for a conventional activated sludge plant. There was a relatively high degree of nitrification during the aeration process but the final effluent still averaged 5.6 mg/l ammonia nitrogen.

The effluent during this six-week investigation was somewhat poorer than that indicated by the average data obtained during 1969 and 1970. Average effluent quality figures for those years are reported as 7 and 9 mg/l for BOD, and 13 and 14 mg/l for SS.

Table 1*

Treatment Data Prior to Chemical Addition

			Phosphorus		Nitrogen					
	BOD	SS	Tot. P	Ortho P	NH_3	Tot. Kj.**	NO_2	Hardness	Alkalinity	pH
Raw Sewage										
Avg.	249	341	14.2	8.1	29	54	trace	225	386	7.8
Max.	488	944	21	11	60	100	-	250	524	8.3
Min.	140	90	9	4.8	12	28	-	180	300	7.5
Primary Effluent										
Avg.	172	126	12.5	8.3	27	46	trace	229	377	7.8
Max.	243	290	20	11	39	94	-	270	430	8.1
Min.	80	40	5	3.2	14	21	-	200	290	7.5
Final Effluent										
Avg.	21	17	8.7	7.6	5.6	8.3	16.6	235	227	7.7
Max.	32	45	14	11	15	22	26	247	294	8.0
Min.	4	2	6.8	3.2	0.1	2.1	7.5	210	170	7.4
Percent Reduction										
Primary	31	63	12	-	7	15	-	-	2	-
Secondary	88	86	30	8	79	82	-	-	40	-
Overall	92	95	39	6	81	85	-	-	41	-

* All units except for pH are expressed as mg/l

** Total Kjeldahl Nitrogen

ADDENDUM

RESEARCH PAPER #W2032

ANAEROBIC DIGESTION OF LIME SLUDGE

Recently, the Newmarket Phosphorus Removal Facility has established the digestibility of lime sludge by the two stage anaerobic digestion system.

When the lime process was started up in March of 1971, the two stage digester had been operating in a normal manner. During the first three months of rather erratic lime addition, gas production increased and the digesters appeared to be operating extremely well. After about 90 days however, a gradual drop in the CO_2 content of the digester gas was noticed with a resultant rise in digester sludge pH. Within about 15 more days, digester gas production dropped off to such a low level that the digesters had to be opened to permit sludge withdrawal and the heat exchanger was shut off. The primary digester was emptied of sludge and the secondary one, half emptied. The primary digester was then used as a holding and partial thickening tank before sludge disposal to agricultural land.

Laboratory studies carried out on the sludge during the following several months established that the pH of the raw sludge decreased fairly rapidly with holding. Originally at a pH of 10 to 10.5 it dropped to about 9.5 in 1 to 1.5 days holding. Observations of the digester holding tank during the same period indicated that some microbiological activity was occurring within the holding tank. By maintaining a sludge depth of 1-1/2 to 2 feet in the primary clarifiers it was found that the raw sludge was being pumped to the digesters at a pH of about 9.5 and at a solids concentration of 11 to 13%. The decision was therefore made to try to establish digester operation once more, so the caps were replaced at the end of February, 1972 and the heat exchanger turned on. The primary digester was allowed to fill and overflow into the secondary digester. Sludge was subsequently drawn from the secondary digester with supernating proceeding in the conventional manner.

By the end of March, gas production was such that the boiler ran on digester gas about one-half the time. By the middle of April heating of the digester was discontinued and waste gas is now being burned in the waste gas burner.

Analyses of the gas indicate an excellent digester gas. Digester sludge is being hauled at a solids content of approximately 12 to 15% . Of considerable interest is that the soluble phosphorus content of the digester supernatant is generally less than 5 mg/l. The pH of the digester sludge at present is between 7.0 and 7.4, which indicates a rapid reduction of pH by the CO_2 produced by anaerobic digestion.

Failure of the digestion process at the start-up of the phosphorus removal facility has been attributed to the frequent overdosing and intermittent addition of lime.

2.0 Lime Treatment Process

2.1 Lime Feeding Program

The phosphorus removal facility was placed in operation on a start-up basis in early March of 1971. As construction of the facility had not yet been entirely completed this period was used primarily to test the operation of the various equipment involved.

Actual continuous operation of the process was begun in early May. From May 3 to June 3, waste carbide lime slurry was fed to the raw sewage at a dosage of 150 mg/l as $Ca(OH)_2$. During this period, phosphorus reductions in the order of 68% were achieved, but the carbide lime was found to be highly abrasive on the metering pump parts. Also,very troublesome carbonate deposits accumulated on all piping and channeling at points where the sewage-lime mixture entered into turbulent contact with air.

On June 4, the lime feed was changed to high-grade hydrated lime at a dosage of 175 mg/l as $Ca(OH)_2$. This feed rate was continued until July 8 during which time phosphorus removals averaged 77% and a decrease in the rate of carbonate accumulation was observed.

On July 9, the lime dosage was further increased to 200 mg/l and this feed rate is continuing as of this date. The remainder of this paper will deal primarily with the operation of the plant from July 9 to December 1 with the addition of high-grade hydrated lime at a dosage of 200 mg/l as $Ca(OH)_2$. A further feed trial using 200 mg/l of waste carbide lime was made from November 15 to 25.

2.2 Load Data of the Phosphorus Removal Process

The aeration process load-data for the actual phosphorus removal process is considerably different from that of the original plant design, the main reasons being the increased efficiency of primary clarification due to the lime, and the reduced aeration volume used. The load data of the respective units are presented as follows:

Primary Clarifier

Sewage flow	1.58 MGD
Detention time	2 hours
Hydraulic surface	875 gal/day/ft^2

Aeration Process

Detention time	6.66 hours
Volumetric BOD loading	18.7 lb BOD/day/1000 ft^3
Organic load ration (F:M)	0.15 lb BOD/day/lb MLSS

Final Clarifier

Detention time	3 hours
Hydraulic surface loading	664 gal/ft^2/day

2.3 Performance of the Phosphorus Removal Process

Table 2 presents a summary of operating data accumulated to date concerning the operation of this facility and represents the averages of data accumulated from 24-hour composite samples of the respective waste streams over a period of 21 weeks from July 9 to December 1, 1971 at a lime dosage of 200 mg/l as $Ca(OH)_2$.

In obtaining the averages for this table, all data was used even though periods of mechanical failure resulted in poor treatment at times. Data obtained during the short trial with waste carbide lime between November 15 and 25 has, however, been excluded.

Looking first at phosphorus removals, the primary effluent averaged about 2.7 mg/l which is considerably above that expected from earlier studies. This rather high value has been attributed to the use of sodium silicate by a local laundry. Laboratory studies have shown that sodium silicate, although having little effect on BOD removals, keeps the calcium phosphate complex in suspension and does not allow it to settle out. Because of this high primary carry-over, total phosphorus reductions across the entire process averaged only about 80%.

BOD and SS removals in the primary clarifier were quite high, being 63 and 75%, respectively. As previously mentioned, because of the reduced load on the aeration section, one of the three aeration tanks was taken out of service. BOD and SS reductions across the entire process were slightly improved over the high removals inherent to this plant, being 96 and 98% respectively.

Table 2

Performance Data of the Phosphorus Removal Process

	BOD	SS	Phosphorus as P		Nitrogen			Hardness	Alkalinity	pH
			Tot.P.	Ortho P.	NH_3	Tot.Kj.	NO_3			
Raw Sewage										
Avg.	227	321	10.3	6.7	28	47	trace	239	391	8.0
Max.	500	880	16	9.5	50	100	-	300	450	8.3
Min.	80	70	5.5	2.7	16	26	-	160	310	7.0
Primary Effluent										
Avg.	84	80	2.7	1.2	21	32	trace	240	374	9.6
Max.	220	170	3.8	2.1	28	48	-	300	450	11.5
Min.	28	35	0.7	0.2	10	17	-	160	240	8.6
Final Effluent										
Avg.	9	7	2.0	1.8	0.8	2.9	19	277	247	8.0
Max.	18	17	2.9	2.4	2.4	4.0	26	390	360	8.6
Min.	3	3	0.9	0.7	0.1	1.0	12	220	170	7.4
Percent Reductions										
Primary	63	75	74	82	25	32	-	-	4	-
Secondary	89	91	26	-	96	93	-	-	34	-
Overall	96	98	80	73	97	95	-	-	37	-

2.4 Sludge Handling and Disposal

Prior to the start-up of the lime process, sludge was treated at the Newmarket plant by a two stage anaerobic digester. Waste activated sludge was returned to the primary clarifiers and drawn off with the primary sludge by 10-inch piston pumps to the first stage digester. Primary sludge was normally pumped at 3 to 4% solids with a 60 to 65% volatile solids contents, about 4900 gallons of sludge being pumped per million gallons during 1970.

With the addition of lime, the sludge was initially handled in the same manner as before, although waste activated sludge is about 50% less because of the reduced organic loading on the aeration process. Sludge is pumped off the primary clarifiers at a rate of about 4900 gallons per million gallons of sewage treated, the same as that before lime addition. The primary sludge solids content however, has increased to an average of 8 to 10% of which about 36% is volatile, and has a pH ranging from 8 to 10.

This sludge is pumped to the digester, which continued to function efficiently in relation to gas and volatile acid production for a period of about 2 months. Subsequent to this, the CO_2 content of the gas dropped off rapidly until gas production decreased to such a point that after about 2 1/2 months, the digesters had to be opened to the atmosphere to permit sludge withdrawal. Since that time the primary stage digester has been used as a holding and settling tank with supernatnat being returned to the wet well. Supernatant is being drawn off at a rate of about 1,000 gallons per million gallons of sewage treated,

the supernatant having a soluble phosphorus content of 5 to 10 mg/l, and a high BOD (2000 mg/l) and SS (1000 mg/l) content. No adverse effects of the supernatant have been noticed on the operation of the plant. Sludge hauled amounts to about 17.7 cu. yd. per million gallons of sewage treated, somewhat less in volume than that before lime treatment. Sludge is being hauled at 10 to 11% solids, however, as compared to 3 to 4% previously.

2.5 General Observations of Phosphorus Removal Facility

2.5.1 Lime Slurry Handling System

In the Newmarket facility lime is stored in a circular concrete tank. Bulk hydrated lime, in 20 ton loads, is blown into the top of the holding tank while water (final effluent) is being added. A slurry of 20 to 25% by weight is achieved but is titrated for exact concentration after each load. The slurry is mixed and maintained in suspension by one of two 6-inch centrifugal recirculating pumps. Lime feed is metered into the rapid mix tank by two flow-controlled positive displacement proportioning pumps.

Problems associated with the slurry handling system have involved inadequate seals on the recirculating pumps (double mechanical seals were later installed), plugging of feed pumps due to foreign materials initially in the slurry tank, clogging of lime feed pump discharge line (the 1-1/2" suction and discharge lines were replaced with 3/4" plastic pipe and an automatic flushing system installed) and faulty operation of the flow control signal.

The lime recirculating pumps have been adequate in maintaining a good lime slurry suspension, and no problems are now being experienced in feeding as high as a 30% by weight lime slurry. No plugging of the 3/4" suction or discharge lines has occurred since the flushing system was installed.

2.5.2 Carbonate Deposits

While lime was being fed to the raw sewage at a dosage of 150 mg/l, very troublesome deposits of calcium carbonate developed on all piping and channeling prior to the influent well of the primary clarifiers. To avoid operational problems, these deposits had to be cleaned off at a maximum of 1 week intervals. At this time it is not known whether the use of the carbide lime contributed to these problems.

At a dosage of 175 gm/l, the deposit build-up was considerably less although still considered as bothersome.

At a further increase in lime dosage to 200 mg/l the deposits all but disappeared. Now a general flushing, with a hose, of piping and channeling is required about once per week with a major clean-up every 3 to 4 weeks.

Carbonate deposits still occur on the primary effluent launders but these are easily washed-down during general maintenance.

When the one aeration tank was emptied after about four months of lime addition, no deposits were noted on any of the tank structures or the tank bottom itself even though one surface aerator had been out of service for about one month prior to emptying.

2.5.3 Sludge Handling and Pumping

To date no problems have been experienced in drawing the sludge off the primary clarifiers even at sludge concentrations of up to 15% solids. In fact, the sludge lines and pumps now require less maintenance than before.

Also to date, no problems have been experienced with the primary clarifier scraping mechanisms due to the lime sludge which at times has been allowed to accumulate to depths of up to 2 1/2 feet and at solids concentrations of up to 15%.

2.5.4 Effect of Lime on Aeration Process

To date no adverse effects on the aeration process have been attributed to the high pH (9.6 average) of the primary effluent even though it has reached as high as 11.5 on occasions.

As previously noted, the lime addition considerably decreases the organic load on the aeration process.

There have been periods of biological upset within the aeration tanks, but similar upsets have occurred during previous years, the cause of which is being investigated.

3.0 Associated Studies

The following is an outline of studies which are being carried out in conjunction with the Newmarket phosphorus removal investigation. These studies have been designed to provide further information concerning individual aspects of the lime treatment process.

3.1 Lime Sludge Centrifugation

From July to September a pilot centrifuge, made available by Sharples-Stokes Division, Pennwalt Corp., was tested using sludge drawn off the primary clarifiers. At a polymer dosage of less than 1 lb/ per ton dried solids, a sludge cake of 25 to 30% solids was achieved at a solids recovery of 95 to 98%. A detailed description of this study is being prepared as Research Paper No. 2030.

3.2 Biological Denitrification

Because of the high degree of nitrification achieved in the aeration process, studies are being carried out to determine the amenability of the aeration mixed liquor to biological denitrification. Preliminary results using a 900 gallon pilot tank indicate nitrogen removals from the mixed liquor of up to 80% as being feasible. Plans are now underway to convert the empty aeration tank to a denitrification tank.

3.3 Sludge Fertility and Toxicity

Greenhouse studies are in progress to give some indication as to the relative fertility and toxicity properties of lime and alum sludges. Two crops, barley and tomatoes, are being grown in

two different soils, a sandy loam and a clay loam under various application rates of each. Results to date indicate an optimum lime sludge dosage of about 30 to 40 tons per acre. Higher alum sludge doses appear to be possible.

3.4 Phosphate Release from Chemical Sludges

Laboratory tests are being carried out to determine the phosphate release properties of chemical sludges under various conditions of holding. Results to date indicate no appreciable release of phosphorus from alum sludges under either aerobic or anaerobic conditions. Lime sludges release small quantities of phosphorus under anaerobic conditions but this release can be inhibited through aeration or small dosages of polyelectrolyte.

3.5 Use of Quicklime

Laboratory tests are being conducted to determine the feasibility of feeding powdered quicklime directly into the flash mix tank.

4.0 Cost Summary

4.1 Capital Cost

The capital cost of the phosphorus removal facility as constructed and installed at the Newmarket WPCP totaled $95,069.95 or approximately $47,500.00 per million gallons plant capacity. The facility as constructed however provides for certain items and services especially supplied for research purposes.

If only those items required for the proper operation of the phosphorus removal process were provided this cost would be somewhat lower. The following is a presentation of the anticipated cost of the facility had it been so designed. This estimate includes adequate standby provisions for flows up to 3.5 MGD with a top capacity of just over 7.0 MGD. The estimate is based on 1970-71 costs.

A - Structural Work	- $22,500.00
B - Mechanical Work	- $19,874.00
C - Electrical Work	- $ 8,247.50
D - Mechanical Equipment	- $ 5,115.00
E - Engineering	- $ 8,971.31
F - Sundry (ie. restoration, painting, bonds etc.)	- $ 4,074.25
Total	$68,782.06

4.2 Operating Cost

At this time the operating cost of the facility can only be estimated. However, the following breakdown is presented as the annual operating cost.

Chemical (96% + pure hydrated lime at 200 mg/l dosage)	$18,048.00
Power (no additional power cost because of reduced aeration)	-
Labour (one operator)	$ 8,000.00
Sludge disposal (no net increase in sludge disposal costs)	-
Sundry (extra fuel, general supplies)	$ 1,000.00
Maintenance (no additional maintenance cost)	-
Total	$27,048.00

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